

Common Base Amplifier with 7- dB gain at 176 GHz in InP mesa DHBT Technology

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Abstract — We report a single stage tuned amplifier that exhibits 7-dB small signal gain at 176 GHz. Common Base topology is chosen as it has the best maximum stable gain (MSG) in this frequency band when compared to common emitter and common collector topologies. The amplifiers are designed and fabricated in InP mesa double heterojunction bipolar transistor (DHBT) technology.

Index Terms — MMIC amplifiers, millimeter-wave amplifier, InP heterojunction bipolar transistor.

I. INTRODUCTION

G-Band (140-220 GHz) amplifiers have applications in wide-band communication systems, atmospheric sensing and automotive radar. High electron saturation velocity of InP material system and deep submicron scaling result in wide-bandwidth transistors with high available gain in this frequency band. In transferred substrate InP HBT process, 6.3 dB gain is reported at 175 GHz with a single stage amplifier [1]. State-of-the-art results in InP HEMT technologies include a three stage amplifier with 30-dB gain at 140 GHz [2], a three stage amplifier with 12-15-dB gain from 160-190 GHz [3], and a three-stage power amplifier with 10-dB gain from 144-170 GHz [4].

Recent work in scaled InP/InGaAs/InP mesa DHBT with 30 nm Carbon-doped InGaAs base with graded base doping, and 150 nm of total depleted collector thickness achieved wide-bandwidth transistors with 370 GHz f_t and 459 GHz f_{max} [5]. In this paper, we describe how this technology is used to realize single stage common base amplifier with a peak small signal gain of 7-dB at 176 GHz

II. INP MESA DHBT PROCESS

The transistors in the circuit are formed from an MBE layer structure with a highly doped 35 nm InGaAs base and 210 nm collector and are fabricated in a triple mesa

process with both active junctions defined by selective wet etch chemistry. Polyimide passivates and planarises the devices. One level of metal deposition is used for circuit interconnects and making the electrical contacts to the transistors and resistors. SiN metal-insulator-metal (MIM) capacitors and coplanar waveguide transmission lines are employed to synthesize the tuning elements. Low parasitic plated airbridges are used to bridge the ground planes.

III. AMPLIFIER DESIGN AND RESULTS

The Spice model parameters for the transistors used in the simulations are extracted using measured two-port S-parameters. The simulations of the amplifiers are performed using Agilent Technologies Advanced Design System software. A planar method-of-moments EM simulator (Momentum) is used to model the coplanar waveguide structures and the MIM capacitors.

The common base breakdown voltage ($V_{br,cb0}$) is more than 7V. The fabricated devices have shown 240 GHz f_t and 290 GHz f_{max} when the devices are biased at $3\text{mA}/\mu\text{m}^2$ current density and 1.7V V_{ce} . The reduction in f_{max} is due to larger base mesa intended to improve yield and relatively poor base ohmics in this process run.

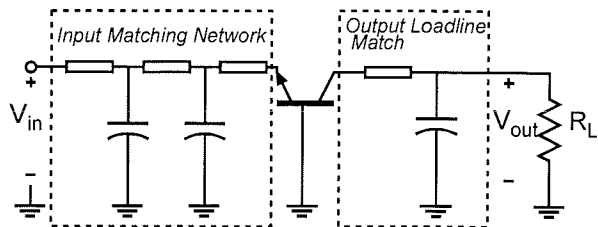


Fig. 1. Circuit Schematic of single-stage common base amplifier.

Common base topology is chosen as it has higher MSG in this band when compared to common emitter and common collector topologies. However, layout parasitics like base inductance (L_b) and collector to emitter overlap capacitance (C_{ce}) could potentially cause instability. Base inductance is due to the thin long base stripes on either side of the emitter. Lack of accurate models to predict L_b create an uncertainty in the stability analysis. Collector to emitter overlap capacitance (C_{ce}) through the polyimide dielectric is process variant as the thickness of the polyimide passivation layer is dependent on the poly etchback which cannot be controlled accurately. However, the overlap is significantly reduced by employing single-sided collector contact as opposed to the more standard double-sided collector contact. This would also increase the collector resistance through the collector contact and access resistances improving the stability further.

The circuit schematic of the single stage amplifier is shown in fig. 1. A chip photograph of a fabricated single-stage amplifier is shown in Fig. 2. The transistor used in the amplifier consists of two separate $0.8 \mu\text{m} \times 12 \mu\text{m}$ fingers. The input matching network is designed for high bandwidth. The output of the transistor is large signal load-line matched for maximum saturated output power as opposed to a small signal match for maximum gain. This power amplifier is designed to obtain 16.5 dBm saturated output power at 180 GHz. However, there might be some degradation in the maximum output power due to process variations and thermal issues. Once the saturated power measurements are performed, they would be presented here.

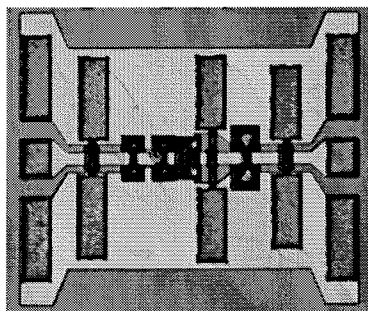


Fig. 2. Chip photograph of the MMIC measuring $0.36 \text{ mm} \times 0.3 \text{ mm}$.

The amplifiers are measured on wafer in the G-band. The measurements are made using an HP 8510C VNA with Oleson Microwave Labs Millimeter Wave VNA extensions. The test-set extensions are connected to GGB Industries coplanar wafer probes via WR-5 waveguides. The amplifier measurements are calibrated using off-wafer

TRL calibration kit. The amplifier exhibited 7-dB small signal gain at 176 GHz (Fig. 3) when biased at 30 mA I_c and 1.0 V V_{cb} . Gain is more than 4 dB from 163 to 188 GHz.

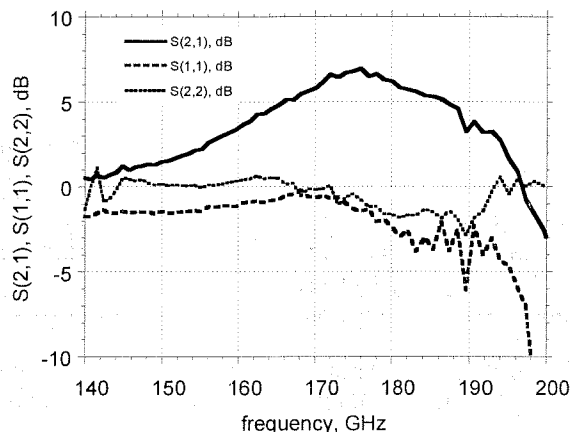


Fig. 3. Measured S-parameters of the G-band amplifier.

VII. CONCLUSION

A single-stage common base G-band amplifier is presented in InP mesa DHBT technology. The amplifier exhibited 7-dB peak gain at 176 GHz. This result demonstrates the potential of InP DHBT technology for high performance ultra-high-frequency millimeter-wave circuit applications.

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